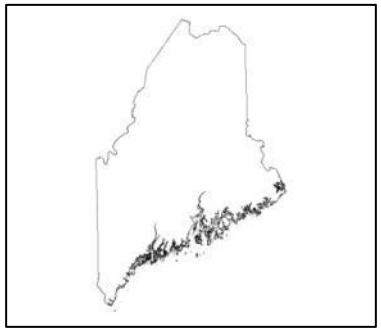
Geologic Site of the Month

April, 2004

Imaging Nearshore Bathymetry using a Personal Watercraft: The MGS Nearshore Survey System



Text by
Peter A. Slovinsky

Introduction

In Maine, sandy beaches only comprise about 2% of the total shoreline, or about 70 miles. Half of that is located in the southern portion of the state, between Kittery and Portland. Beaches in Maine are typical of many barrier beach systems along the east coast in terms of their overall morphology and governing processes (Figure 1).

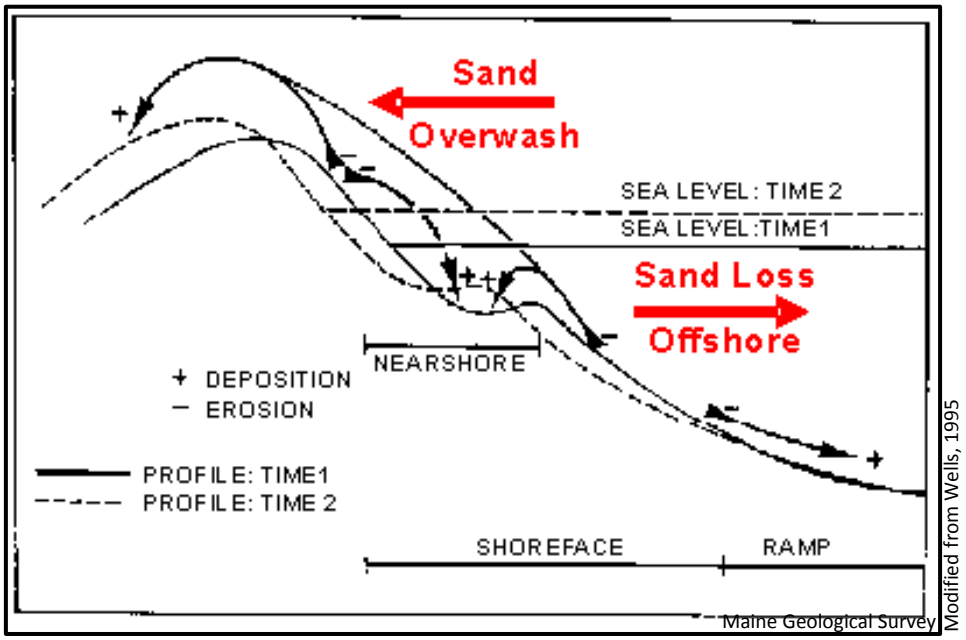


Figure 1. Barrier Beach morphology and processes. Barrier beaches are constantly changing in response to hydrodynamic forces such as tides and waves, and a rising sea level. Storms tend to erode beaches by moving sediment from the beach and dune offshore into intertidal and subtidal bars. Studies show that some sediment never returns to the beach the following year.

Project Background

However, sand supply in Maine is much less plentiful than in other areas of the east coast, making beaches a valuable yet limited resource to the state.

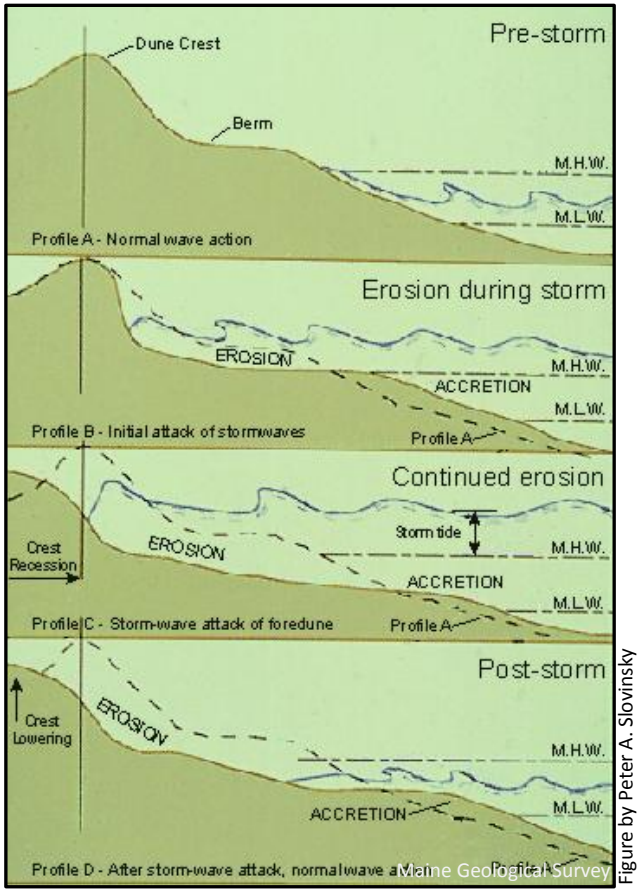


Figure by Peter A. Slovinsky

Figure 2. Beach processes during storm events.

Project Background

In the past, the Maine Geological Survey (MGS) studied changes in Maine's beaches on a seasonal basis through the analysis of beach profiles. We have found that huge volumes of sediment are exchanged between the exposed beach and the subtidal portions of the beach during different times of the year. However, the intertidal and subtidal portions of the beach (i.e., less than 30 feet in depth), within which the majority of sediment moves and is located, has not been studied closely due to past difficulties in surveying within the surf zone.

In 2002, MGS received a grant from the Maine Technology Institute for a project entitled "Three-Dimensional Beach and Nearshore Bathymetric Surveys and Sand Budgets", that involved the development of a Nearshore Survey System (NSS). The NSS utilizes state-of-the-art positioning, depth sounding, and current monitoring technologies and is revolutionizing the way MGS can study the beach and nearshore sandy environments. It enables us to monitor and analyze spatial and temporal changes in the intertidal and nearshore subtidal beach environment, a previously unstudied portion of the beach system due to difficulty of access (in the surf zone) and limited positioning technology. Similar surveying systems have been developed for use in the coastal zones of Washington-Oregon, California, Texas, Virginia, Florida, and North Carolina (Dugan and others, 1999; Gelfenbaum, 1999, Innerspace Technology; McMahan, 1999; Ruggiero and others, 2000).

The NSS platform is a personal water craft outfitted with high precision positioning, depth sounding, and current monitoring equipment. The system is comprised of a base station and a rover platform, both which incorporate the use of Real Time Kinematic Global Positioning Systems (RTK-GPS).

The Base Station

RTK-GPS allows cm-level accuracy surveys in real-time, providing for almost immediate and accurate positioning data that is necessary for surveying and quantifying beach changes. The NSS base station is comprised of an RTK-GPS receiver, a tripod with antenna, several radio modems, a data logger (to initiate the GPS equipment), a laptop computer, and a marine gel 12-V battery (Figure 3).

Figure by Peter A. Slovinsky

Figure 3. NSS "base station" equipment.

The Base Station

The GPS receiver acquires positioning information through the antenna from up to 12 satellites in orbit over the earth, and telemeters positioning corrections to the rover GPS located on the rover portion of the NSS. At the same time, position and depth data are being telemetered from the NSS rover to the laptop computer via the radio modem at 1 point-per-second. The laptop is running special surveying software which logs position and depth data every second. Communication between operators of the base station and the rover is maintained through 2 handheld VHF radios.

Rover Platform

A personal watercraft (PWC) is the basis for the NSS rover platform. The watercraft was selected based on its storage capacity, size, and environmentally friendly 4-stroke engine. Before system integration, MGS staff spent 10 hours on the watercraft in various conditions on lakes and in the ocean in order to break in the engine according to the owners manual and familiarize themselves with handling the PWC. This was a tough job, especially during the late Maine summer (Figure 4), but someone had to do it!

Figure 4. Personal watercraft used as the basis for the NSS rover platform.

Rover Platform

The rover portion of the system is outfitted with various positioning and depth-sounding equipment, including an RTK-GPS receiver with internal radio modem, a depth sounder, a helm display, a radio modem, and 2 antennas (GPS and radio). The depth sounder, GPS receiver, and radio modem are mounted within the front compartment of the PWC, which flips open for easy access, while the helm display is mounted on the handlebars. Instruments within the front compartment are mounted on a special frame that slides up, allowing easy access to the depth sounder and GPS (Figure 5).

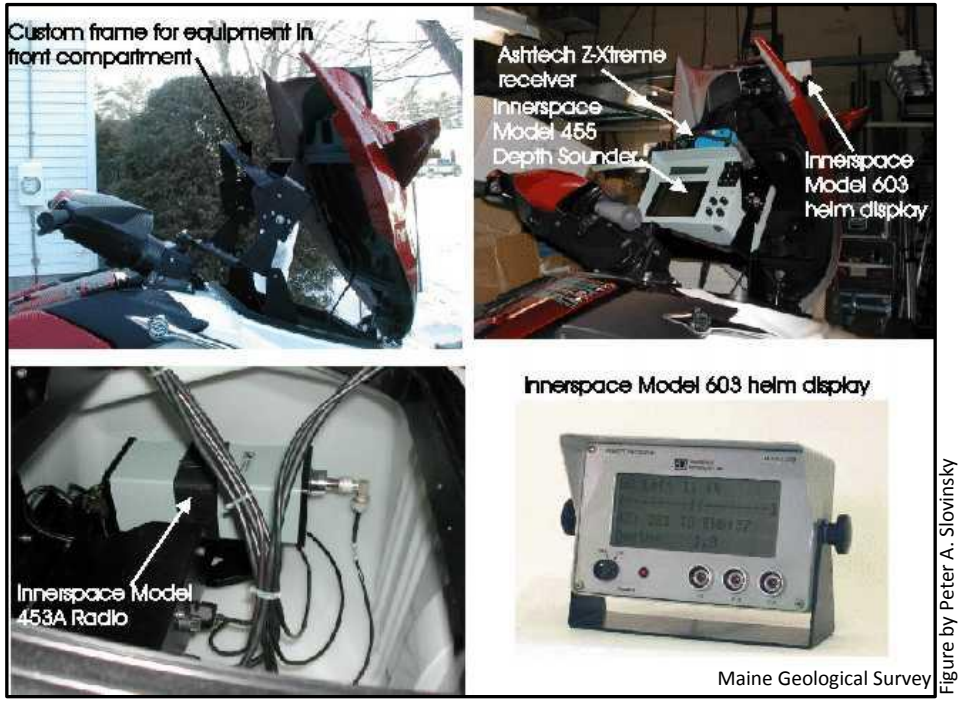


Figure 5. NSS "rover" helm equipment including custom frame, receiver, depth sounder, radio, and helm display.

Rover Platform

The depth sounder transducer, which sends an acoustic signal that bounces off of the sea bottom, a gel 12V marine battery, and GPS and radio antennas are mounted on the stern of the NSS (Figure 6). The custom-manufactured bracket for the transducer has a special "kick-up" feature in case the transducer strikes an underwater object during operation. An additional custom bracket for a current meter has also been constructed (see below, Current Monitoring).

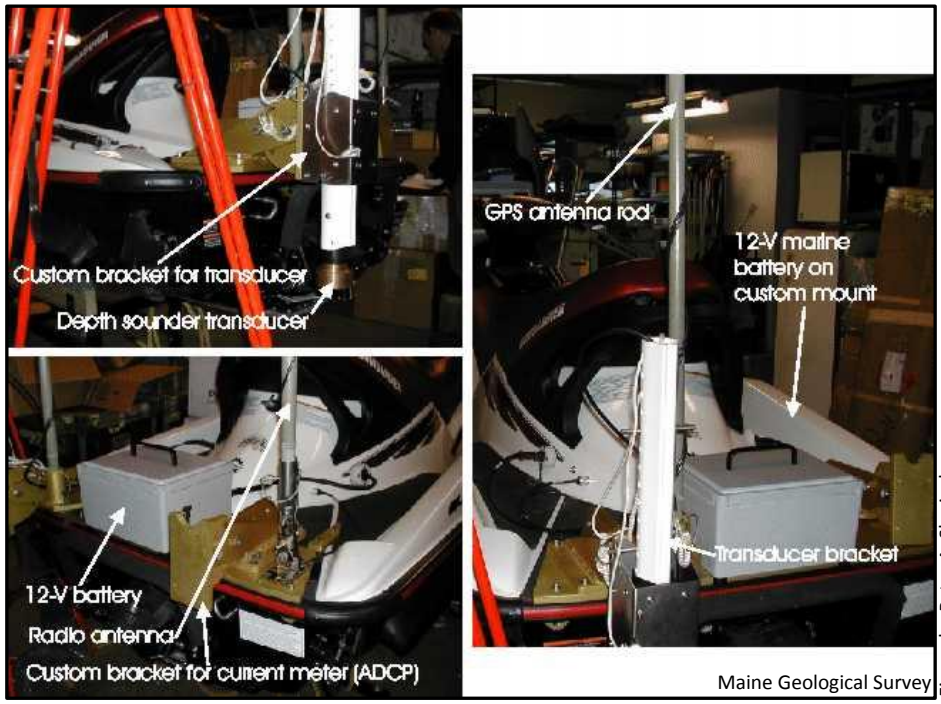


Figure 6. NSS "rover" stern equipment including depth sounder transducer, marine battery, GPS antenna, and radio antenna.

Rover Platform

The depth sounder captures depth readings at 1 point-per-second, tags each depth reading with an XYZ positioning (horizontal and vertical coordinates, and elevation) from the GPS, and telemeters the data back to the shore-based laptop computer for data logging. At the same time, the helm display shows the NSS operator the direction and speed they are traveling in relation to pre-set track lines; it receives positioning updates from the shore-based GPS. This enables the operator to focus on driving the PWC and staying on set track lines, and not worrying about data logging. All equipment is mounted on the PWC with quick releases for easy dismantling. Communication between the operator of the PWC and the shore-based data manager is maintained using handheld VHF radios.

Current Monitoring

The NSS rover is being outfitted with equipment that enables it to conduct current monitoring studies. The current monitoring equipment package is being purchased and will be comprised of an acoustic doppler profiler (ADP) housing and transducer, an onboard computer and a solid state flash drive housed in a waterproof enclosure, and a small 10-inch customized monitor mounted on the handlebars of the PWC (Figure 7). The computer and ADP housing will be mounted within the front compartment of the PWC. A waterproof keyboard will be used to send commands to the computer to run current monitoring software. The final piece of equipment is a temperature and conductivity meter, which measures the salinity of the water to make sound velocity corrections.

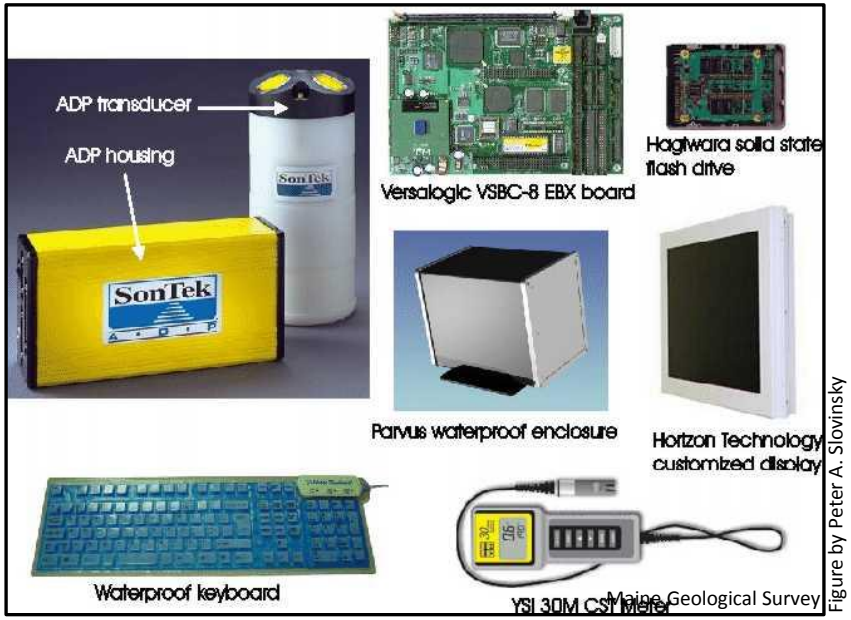


Figure 7. NSS "rover" current monitoring equipment including ADP transducer, waterproof keyboard, and waterproof enclosure.

Current Monitoring

The ADP underwater transducer will be mounted on the stern of the NSS. The ADP sends and receives an acoustic pulse which measures current velocity and direction in a vertical profile through the water column (Figure 8). The computer will run current monitoring software and receives inputs from the ADP (velocity and direction), the GPS (XYZ positioning), and the depth sounder (water depth, h). The special solid state flash drive has no moving components and is much more shockproof than regular hard drives. The small monitor shows the PWC operator the status of current data logging and enables them to initiate or terminate data logging with the touch of a waterproof keypad, mounted in a small compartment directly in front of the operator.

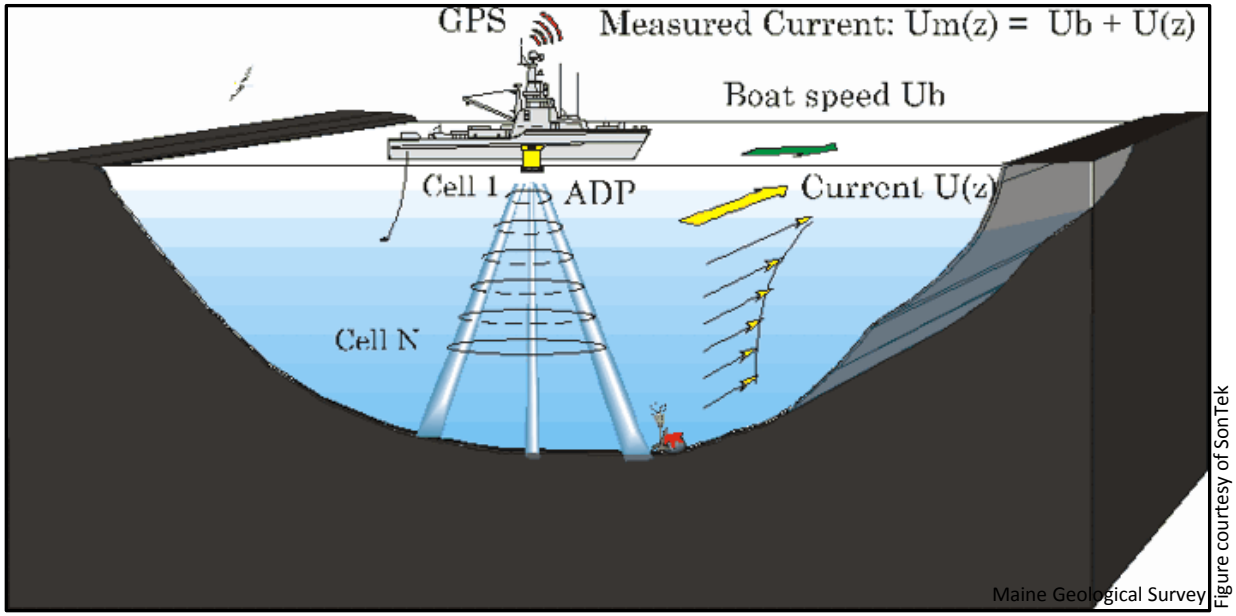


Figure courtesy of SonTek

Figure 8. Current measurements from a vessel.

Current Monitoring

The fully integrated NSS, showing the flow of positioning information and various data types, is presented in Figure 9. The integration and custom construction of equipment brackets for the positioning and depth equipment was completed by Innerspace Technology, Inc., of Waldwick, NJ. Innerspace has integrated several Personal Watercraft Surveying Systems for other organizations.

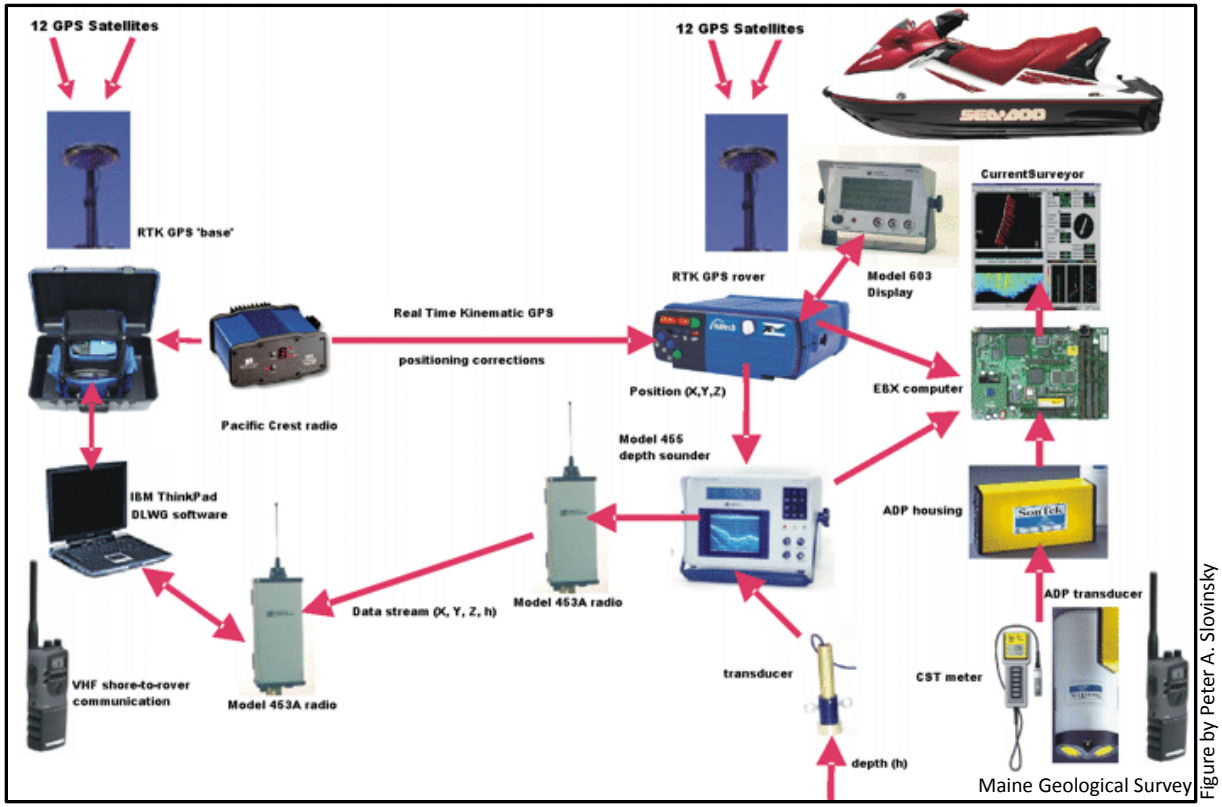


Figure by Peter A. Slovinsky

Figure 9. NSS showing the flow of positioning information and various data types.

What will we be able to do with the NSS?

The unanswered question in Maine in terms of its sandy beaches is what happens to sand, especially at the nearshore subtidal portion of the beach? Meteorological and wading depth beach profile data suggest significant interannual variability in the intertidal beach profile and the potential for nearshore (subtidal) storage and movement of sand in both shore-parallel and shore-normal directions (Dickson, 1999; Heinze Hill and others, 2002). The NSS will be able to 'fill the data gap' between the supra-tidal/inter-tidal data collected by volunteers in the State of Maine Beach Profiling Project and bathymetric data collected farther offshore with conventional research vessels, helping to answer the question of "where the sand goes."

In addition to helping to answer this question, the NSS brings cutting edge surveying technology to MGS for other applications. Using the RTK-GPS equipment, we can now conduct high-precision land-based surveys to map features such as the mean high water line, vegetation line, washover fans, and other features indicative of shoreline changes. We will also be able to utilize the current monitoring equipment from a variety of different platforms. However, the majority of the NSS work will be in the nearshore zone, for which it was designed.

NSS Operation

The NSS requires a minimum of two people to operate: one operating the personal watercraft 'rover', and one operating the base equipment to ensure data logging quality. The system requires that the 'base' station be set up on a point of known position (XY) and elevation (Z). Therefore, the first step in field work is to establish base benchmark locations that can be used during nearshore surveying field work. This is done by setting the base GPS equipment on a known benchmark (Figure 10), and surveying in control points (with known horizontal and vertical coordinates) to refine the base position and establish a reference grid. Once this is done, the base station is ready to receive information from satellites, and begin broadcasting corrections to the rover GPS that is mounted on the NSS for nearshore surveys, or worn inside a backpack for land-based surveys.

Figure 10. RTK GPS surveying. The base station is set on a location with known X, Y, and Z coordinates. Control points, also of known coordinates, are used to relate the base location to a known datum. Once the control points are set, the base receives data from up to 12 satellites and broadcasts positioning corrections to the rover GPS.

NSS Operation

Nearshore surveying will mostly occur along pre-determined track lines so that the lines may be repeated in the future. However, the NSS has the capability to do "on the spot" surveying as well due to the RTK-GPS equipment. With the NSS, surveying can be conducted in both cross-shore and alongshore directions, resulting in high resolution colorful 2-D and 3-D images of nearshore bottom topography similar to the ones shown in Figure 11.

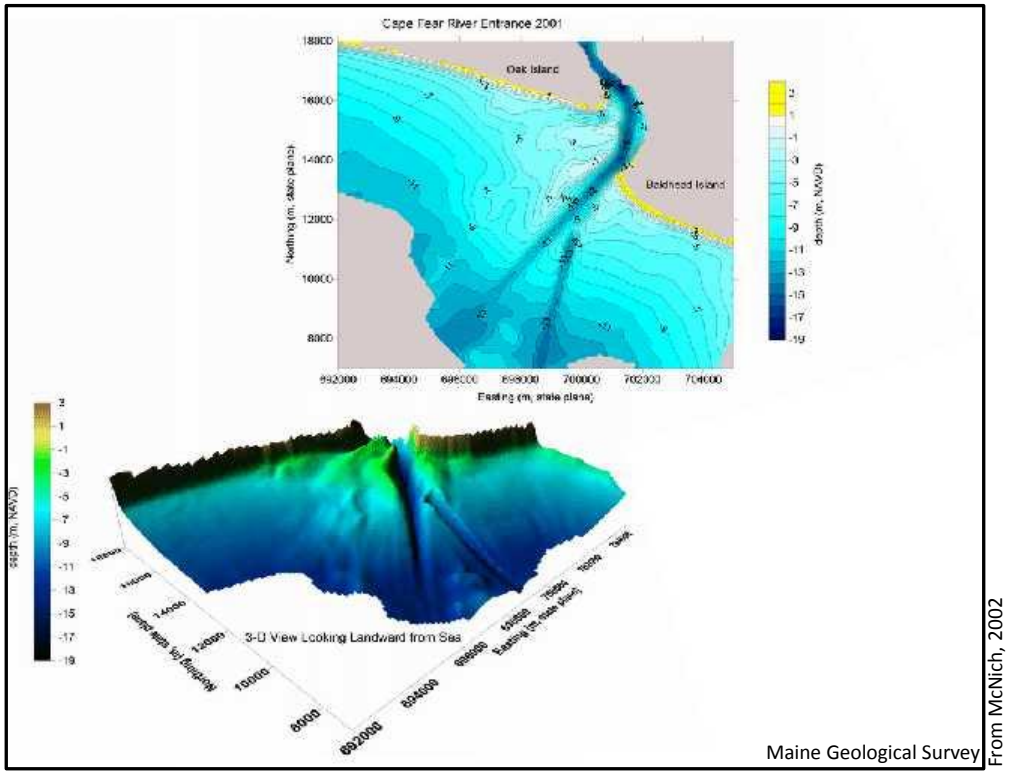


Figure 11. Two- and three-dimensional images of bathymetry.

NSS Operation

This data can be quantitatively analyzed to determine volumetric changes in the beach. Current monitoring data will be analyzed to help infer sediment transport directions and for other uses (Figure 12, and see below).

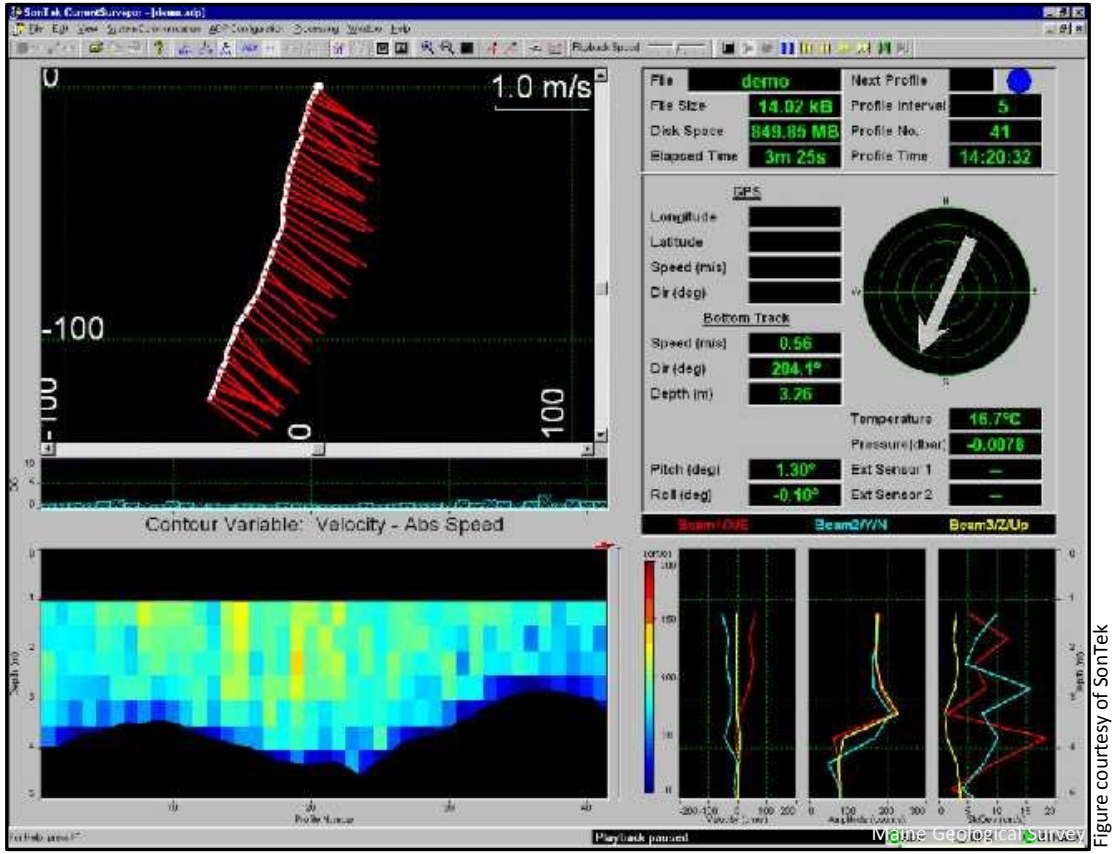


Figure courtesy of SonTek

Figure 12. Current velocity structure and data shown on the Current Surveyor software.

Specific NSS Projects

One project that specifically will benefit from use of the NSS is the proposed jetty modification and/or beach nourishment at Camp Ellis in Saco, Maine. The NSS will be used to monitor the effectiveness of any jetty modifications that are undertaken to help curtail erosion problems, and to monitor the fate of any beach nourishment that occurs.

The NSS will be used to complement existing monitoring programs that document changes in the intertidal to dry beach. The State of Maine Beach Profiling Project is a volunteer-based beach profile monitoring program organized by MGS, the Marine Geology Working Group at the University of Maine, Maine Sea Grant/University of Maine Cooperative Extension, and the Maine Coastal Program. On a monthly basis, volunteers collect profiles of the subaerial-to-intertidal portions of selected sandy beaches. This program provides adequate data to document some temporal and two-dimensional spatial variations of the subaerial-to-intertidal beach. The NSS will be used to expand this program to document seasonal changes of the entire active beach profile, from the sand dune seaward to about -30 feet. Pre-determined cross-shore transects will be surveyed spring, summer, and fall, from the dune seaward to approximately -30 feet. This will enable MGS scientists to monitor and analyze a previously unstudied portion of the active beach system. For current monitoring, the NSS will be used this spring and summer for two projects. MGS will conduct current surveys for a project titled "Current Studies for Swim Beach Response Planning" in an attempt to correlate beach water quality response to different meteorologic conditions for the Healthy Maine Beaches Program. In addition, the NSS will be used as part of a project titled "Tidal Current Inlet Studies for Oil Spill Response Planning" for the Maine Department of Environmental Protection Emergency and Spill Response Program. The NSS will be used to determine peak flood and ebb tidal current conditions in the Presumpscot River in order to determine successful booming strategies to protect the estuary in the event of an oil spill in Casco Bay.

References and Additional Information

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Related Websites on Beach Profiling in Maine

State of Maine Beach Profiling Project
Maine Sea Grant/University of Maine Cooperative Extension Beach Profiling
MGS Field Locality Mile and Half Mile Beaches at Reid State Park
MGS Field Locality Laudholm and Drakes Island Beaches - Before and After Beach Nourishment
MGS Field Locality WWII Rockets Removed from Beach at Reid State Park
MGS Field Locality Shells on the Beach

Acknowledgements

We would like to thank the following organizations for making the NSS project possible:

- Maine Technology Institute
- Maine Sea Grant Research
- Maine Department of Environmental Protection
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We would like to acknowledge the following for providing the equipment that has been purchased to-date for the NSS project:

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- Pacific Crest Corporation
- Parvus
- Sea Doo
- SonTek

**The use of trade names in this report is for descriptive purposes only and does not constitute endorsement by the MGS.*